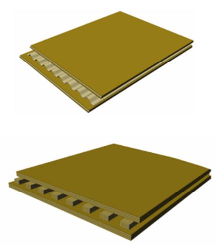
Elaboration of design guidelines for all-plywood sandwich panels

Edgars Labans, Kaspars Kalniņš
Riga Technical University, Institute of materials and structures
edgars.labans@rtu.lv, kaspars.kalnins@sigmanet.lv

ABSTRACT/ INTRODUCTION



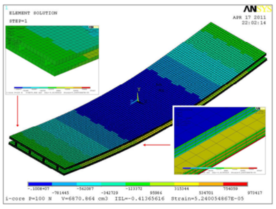
All-plywood sandwich panels, made from a plywood sheets and profiled plywood core, could offer convenient alternative to the conventional (>25 mm total thickness) plywood sheets. In particular for engineering fields demanding lightweight solutions as surface and waterborne transport industry. As main drawbacks of such product are expensive development costs combining complex analysis tasks and prototype manufacturing.

In order to elaborate the optimum design and design guidelines one of most convenient option for analysis of the 3D plywood panels is Finite Element Method (FEM) integrated in commercial computer codes as ANSYS [1] and recognised by industry. For optimum design the parametrical model should be developed with parametrical input variables corrugated and ribbed core allowing to save the development time in optimisation of cross-section parameters employing metamodelling methodology as shown [2,3]. Methodology consist of design of computer experiments, numerical analysis in sample points, approximation of the response data by parametrical or nonparametric functions and finally developed optimum design guidelines. These design guidelines can serve engineers and end users to tailor appropriate sandwich profile type according their demands, without further using structural design software.

MATERIALS AND METHODS

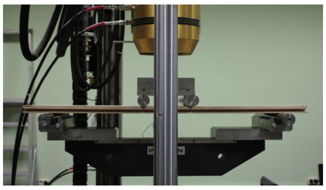
FEM MODELLING

Parametrical models of the panels was created with variable cross section parameters and bending set up, according to EN 789. ANSYS 4-node shell element SHELL 181 has been employed, assuming that each ply has thickness of 1.3 mm and transversal isotropic material properties of birch. Numerical model geometry was created to match the panel dimensions as close as possible.



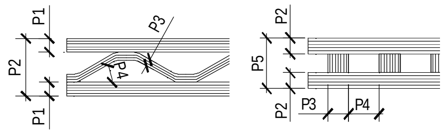
EXPERIMENTAL

Several types of all-plywood sandwich panels has been tested in 4-point bending mode according to EN 789. In total 51 panel has been tested on INSTRON 8802. geometrical parameters of the panels is length -1200 mm, width – 300 mm, height – 30 mm. Both strain and deflection measurements have been recorded. For sandwich panels with corrugated core strain gauges have been attached also on core surface.



OPTIMISATION

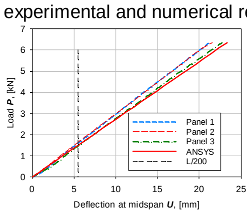
Using metamodelling functions optimal cross section parameters have been elaborated for evaluation of most efficient bending stiffness versus weight ratio combination. Four/five design variables have been used to describe different cross-section parameters. Surface, stiffener and corrugated ply thicknesses have been described with plies count. Upper and lower bound as well as increment step of variables has been set. Section thickness may vary between 25 and 50 mm. Surface plywood plies count my vary between 3, 5 and 7 plies.

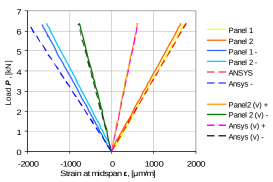


RESULTS AND DISCUSSIONS

VALIDATION OF FEM MODEL

In order to validate the numerical model of the plywood sandwich panel, experimental strain and deflection measurements have been compared with response values extracted from numerical simulations. The numerical and experimental deflection and strain curves are provided in following figures with obtained discrepancy between experimental and numerical results not exceeding 15 %.





One can note that load deflection curves have linear behaviour (until deflection limit 20 mm), indicating the elastic deformation of the panels. Numerical results practically match the experimental load/deflection values. Negative strain values acquired from strain gauges attached on the top of the panels in compressed area.

OPTIMISATION RESULTS AND DESIGN GUIDELINES

Design of computer experiments has been made with in-house tool EdaOpt employing MSE design space filling criteria. A sampling file containing 150 combinations of variables have been created. All these combinations of variables have been automatically calculated by ANSYS and approximation functions of panel volume and deflection have been elaborated using VariReg software. Adaptive Base Function Construction method has been used to construct multiorder parametric polynomial approximation functions. The goal of the optimisation was to reach the greatest difference between gain in weight reducing and loss of load carrying capacity, comparing with numerically simulated traditional plywood board. Optimal values of variables have been found using approximation functions and MS Excel Solver software. Variable parameters for every sandwich panel thickness step summarized in tables for both panel types.

Panels with ribbed core

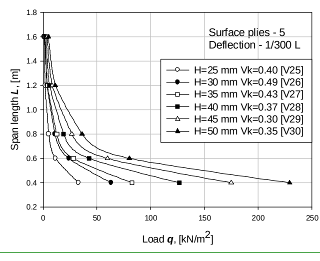
Variables	V25	V26	V27	V28	V29	V30
P1	3	5	5	7	7	7
P2	3	5	7	7	7	7
P3	5	5	5	5	5	5
P4	0.04	0.045	0.031	0.033	0.25	0.018
P5	*0.025*	*0.03*	*0.035*	*0.04*	*0.045*	*0.05*
Vs, cm^3	3311	4951	6240	7140	8520	8763
Vs-Vp,%	60	49	46	46	43	47
Us-Up, %	20	20	20	20	20	20
Total, %	40	29	26	26	23	27

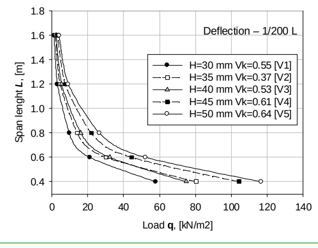
Panels with corrugated core

Variables	V1	V2	V3	V4	V5
P1	3	5	5	3	3
P2	*0.03*	*0.035*	*0.04*	*0.045*	*0.05*
P3	5	5	3	5	5
P4	60	60	60	60	60
Vs, cm^3	3966	6600	5580	5300	5360
Vs-Vp,%	55	37	53	61	64
Us-Up, %	22	14	30	35	42
Total, %	33	23	23	26	22

Sandwich panel volume parameter has been marked as Vs in contrary to homogenous plywood volume as Vp. Respectively Us and Up – deflections for sandwich panels and plywood panels of the same thickness. To estimate efficiency of cross section parameters deflections and volumes of sandwich panels were compared with homogenous plywood values. Difference between sandwich panel and pure plywood volume has been divided by sandwich panel volume to acquire volume reduction (%) using sandwich structure. Similar action has been to asses the deflection values for both structural types. The parameter Total stands for difference between volume gain and deflection loss (%). In average a total gain value in comparison with homogenous plywood is 25 %.

For several panels with optimal cross section parameters, design guidelines have been made to easy asses load carrying capacity at different span lengths. Guidelines sorted by surface thicknesses. Deflection limit set to 3 or 5 % of span length.





CONCLUSIONS

* Numerical model with multilayer plywood structure is suitable for performing virtual bending tests for sandwich panels with corrugated core – obtained discrepancy between experimental and numerical results not exceeding 10 - 15%.

* In particular combinations of variables optimised sandwich structure could be up to 40 % weight effective comparing with conventional plywood boards, loosing only 10-20 % of the load carrying capacity.

* Design guidelines have been elaborated to assess allowable load carrying capacity values for certain span length.

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